USDA

Natural
Resources
Conservation
Service

Soil
Quality
Institute

SOIL QUALITY THUNDERBOOK

June 1999

A Note About Soil Quality and the Thunderbook

What does soil quality mean to you? Soil that is highly productive and profitable now and in the future? Soil that is in harmony with its surroundings? Whether your perspective is economic, aesthetic, or a combination of these views, a key to soil quality is that soil functions within a larger system.

Soil quality, then, is the capacity of a soil to function. Healthy soils are able to:

- Sustain plant and animal diversity and productivity.
- Regulate and partition water and solute flow.
- Filter and buffer potential pollutants.
- Store and cycle nutrients.
- Support buildings and other structures and protect archaeological treasures.

Most people are aware of the importance of air quality and water quality, but only recently are they realizing the significance of soil quality. The Natural Resources Conservation Service has over 60 years of experience in protecting the soil resource and in maintaining its ability to function within the landscape. Because soil quality is a result of soil management, it is an integral part of our technical assistance activities. Helping farmers, ranchers, and other land managers to understand and apply soil-building technologies and practices will assure a healthy resource base well into the future.

The Soil Quality Institute offers this thunderbook to help you build a handy reference for soil quality information. Thunderbooks are a traditional agency marketing and educational tool. They have been customized and used by conservationists since the early years of the Service. The intent of thunderbooks at that time was the same as it is today–a place to store and retrieve the materials that you decide are most important and useful to you and your customers. We have supplied tabs and suggested topics for easy organization of the soil quality material you already have and that you will gather. The final section, Resources and References, will start you on your way to accessing sources of soil quality information and educational materials.

We welcome your suggestions about soil quality information, technology, and training needs. Visit our Web site at http://www.statlab.iastate.edu/survey/SQI/sqihome.shtml.

Soil Quality Institute Staff

Soil Quality Institute

Our Team

- Craig Ditzler, Director
- Mike Hubbs, Agronomist
- Lee Norfleet, Soil Scientist
- Cathy Seybold, Soil Scientist
- Arlene Tugel, Soil Scientist

Our Work

Mission

Cooperate with partners in the development, acquisition and dissemination of soil quality information and technology to help people conserve and sustain our natural resources and the environment.

Functions

- Leadership in soil quality
- Technology development for soil assessment and management
- Technology transfer and training.
- Building partnerships.
- Customer service delivery.
- Marketing for stewardship.

Strategies

- Integrate soil quality considerations with NRCS programs and technical guidance materials.
- Cooperate with training organizations to increase our training capacity.
- Provide information to multipliers to expand the transfer of technology and information
- Promote a national consciousness of the importance of managing resources for long-term health and productivity.
- Cultivate new and existing partnerships for effective and efficient relations.

Our Focus on the Future

Trends of intensified crop production to meet world food demands, pressure on nonrenewable resources and global climate changes provide a long-term focus on managing for soil quality. In the short-term, soil quality considerations are essential for on-farm decisions about practices such as conservation tillage and pest and nutrient management. They are also important to other issues, including water and air quality, rangeland health, carbon sequestration, and agency performance. SQI projects, products, and services are designed to address such issues and to assist customers in making informed decisions.

Goals

- Design a formal training course in soil quality.
- Provide the opportunity for Soil Health Card training to the 1890s schools.
- Develop a field guide for assessing soil quality.
- Determine the effects of irrigated agriculture on soil quality.
- Develop a field procedure to compare farming systems and to identify those that enhance soil quality.
- Define the agency's outcome performance measure for soil quality.
- Craft a marketing strategy for soil quality.
- Investigate remote sensing applications.
- Formulate a point-scale Soil Quality Index.
- Quantify the value of enhancing soil quality.

Learn more

Visit the SQI web site at www.statlab.iastate.edu/survey/SQI/sqihome.shtml, or call Craig Ditzler at 515-294-4592.

Managing soil for today and tomorrow.

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SOIL QUALITY THUNDERBOOK
Table of Contents

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Soil Quality Test Kit Guide

What's it for?

- To compare soils under different land management systems.
- To track changes in soil quality over time.
- To demonstrate the effects of practices, such as conservation tillage, on soil quality.
- To create an awareness of the importance of soil quality.

Who's it for?

- NRCS and Conservation District staff
- Farmers and ranchers
- Ag professionals
- Educators

What's in it for you?

- The Guide has two user-friendly parts. The **Instructions Section** describes the relatively simple procedures for 12 diagnostic tests of the physical, chemical, and biological properties of soil. **(See back of this page.)** It includes worksheets for recording data and calculating results. It also lists types and sources of supplies needed to build a field test kit. The **Interpretations Section** provides information for use in evaluating, primarily for agricultural purposes, the results of each test in the kit.

- Procedures were **field tested** by NRCS state and field staffs in each region, whose comments led to further refinement of test procedures. The Guide was developed by the Soil Quality Institute in partnership with the Agricultural Research Service and the National Soil Survey Center.

- The Guide offers **educational and marketing opportunities** for field days and other special events.

- The Guide is a dynamic document. The Soil Quality Institute welcomes suggestions for additional tests and interpretive information to incorporate in **future versions** of the Guide. Please forward your comments to Cathy Seybold at 541/737-1786; email seyboldc@ucs.orst.edu.

- Single copies of the Guide are available from the Institute at 2150 Pammel Drive, Ames, IA 50011; FAX: 515/294-8125 or from the SQI Web site.

For more information about soil quality or about the Institute, visit our Web site at http://www.statlab.iastate.edu/survey/SQI/sqihome.shtml.

(Over)

Soil Quality Test Kit Guide

Kit Tests

1. **Measuring Soil Quality**-discusses and gives guidelines for sampling and site characterization.
2. **Soil respiration**-measured using an aluminum cylinder that is 6 inches in diameter and 5 inches long. The cylinder is capped and accumulated carbon dioxide respired by soil organisms and plant roots is measured. Respiration provides a measure of biological activity, which is related to nutrient cycling and breakdown of pollutants in the soil.
3. **Infiltration**-measured using the same cylinder as in the soil respiration test. Infiltration is important to reducing runoff and storing water in the soil for plant growth.
4. **Bulk Density**-measured by inserting a 3-inch-diameter cylinder 3 inches into the soil surface and removing the intact soil. Bulk density is related to root growth, biological activity, and movement of water and air in the soil.
5. **Electrical Conductivity (EC)**-measured with a pocket EC meter. It provides a measure of salinity (excess salts) in the soil.
6. **Soil pH**-measured with a pocket pH meter. It relates to nutrient availability and plant growth.
7. **Soil Nitrate**-measured by dipping nitrate test strips into the solution filtered from a 1:1 ratio soil/water mixture. Soil nitrate levels are important for plant growth and water quality.
8. **Aggregate stability**-determined by sieving soil in water and measuring the amount of aggregates greater than 0.25 mm in diameter that remain on the sieve. Aggregation is important in decreasing erosion, increasing water and air movement, and preserving organic matter in the soil.
9. **Soil slaking**-determined by putting soil fragments or aggregates in water and estimating the degree of slaking. Slaking is important to reducing erosion and development of surface crusts.
10. **Earthworms**-determined by counting the number of earthworms found in a square-foot hole. They are important in nutrient cycling and creating large pores for water and air movement in the soil.
11. **Soil Physical Observations and Estimations**-shows how to observe soil structure and root patterns and to estimate topsoil depth, penetration resistance, and soil texture in the soil profile. These properties are important to the physical environment for plant growth.
12. **Water Quality**-estimates salinity and nitrate and nitrite levels in water.

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Soil Biology Primer

What's it for?

- To introduce readers to the diversity and functions of the organisms that form the living component of soil--the soil food web.
- To help people understand the importance of the soil food web to land management decisions.

Who's it for?

- Farmers and ranchers
- NRCS and Conservation District staff
- Ag professionals
- Educators and students

What's in it for you?

- **Part I** of this color publication consists of eight units that describe the soil food web, its effects on soil health, and the major groups of organisms that form the food web--bacteria, protozoa, nematodes, arthropods, fungi, and earthworms. **Part II** will address applications of soil biology principles. Topics being considered include the effects of management and conservation practices on the soil food web and the relation of the food web to rangelands, composting, carbon sequestration, and nitrogen cycling.
- The Primer can be used to support NRCS marketing initiatives, including Earth Day and Backyard Conservation, as well as to provide information for resource considerations for Core Four practices.
- The Primer is an educational tool to stimulate discussions about soil, its biology, health, management, and conservation. The information can also be used in developing training materials on issues related to soil quality, such as pest and nutrient management.
- Part I is available from NRCS offices and from the SQI at 2150 Pammel Drive, Ames, IA 50011; FAX: 515/294-8125.
- The SQI welcomes suggestions of topics to incorporate in Part II of the Primer. Please forward your comments to Arlene Tugel at 505/646-2660; email atugel@NMSU.edu.

The Soil Quality Institute developed the Primer in partnership with the Conservation Technology Information Center, Oregon State University, and Ohio State University.

For more information about soil quality or about the Institute, visit our Web site at http://www.statlab.iastate.edu/survey/SQI/sqihome.shtml.

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Soil Quality Card Design Guide
…a locally led conservation tool.

What's it for?

- To provide a **step-by-step process** for leading farmers in identifying soil quality indicators and in developing a do-it-yourself soil quality rating system--a Soil Quality or Soil Health Card.
- To develop Soil Quality Cards **for farmers by farmers** that are adapted to local conditions and needs.

Who's it for?

- Farmers
- NRCS, Conservation Districts, and RC&D Councils
- Extension specialists
- State conservation agencies

What's in it for you?

- **Part 1:** Overview of the Guide summarizes the concepts and benefits of Soil Quality Cards and farmer meetings. **Part 2: Getting Organized** discusses preparations for conducting the farmer meeting. **Part 3: Putting the Card Together** focuses on the nuts and bolts of the farmer meeting and of field-testing and production of the card. **Part 4: Taking Next Steps** discusses marketing and distribution strategies and integrating the card into established NRCS activities. **Part 5: Tool Box** offers templates, tips, and references for a successful project.
- In the spirit of outreach and locally led conservation, farmer meetings offer opportunities for dialogue and idea sharing, strengthening partnerships and trust, and blending the scientific knowledge of conservationists with the common-sense experience of producers.
- Soil Quality Cards are tools to help farmers inventory and assess resources, evaluate planning alternatives, and monitor practice effectiveness over time. They are also educational tools to initiate discussions about soil quality and soil management.
- The process was field tested through cooperative efforts of the SQI; University of Maryland; Oregon State University; Cooperative Extension Service; and NRCS staffs and farmers in OR, MD, MT, ND, and NM.
- Single copies of the Guide are available from the SQI at 2150 Pammel Drive, Ames, IA 50011; FAX: 515/294-4369 and from the SQI Web site.

For more information about soil quality or about the Institute, visit our Web site at http://www.statlab.iastate.edu/survey/SQI/sqihome.shtml.

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This is an example of a Soil Quality Card designed by farmers in the Willamette Valley of Oregon.

Willamette Valley

Soil Quality Card

Date: ______________ Crop: ______________ Soil moisture: ❑ Good for planting ❑ Too dry for planting ❑ Too wet for planting

Field location: ______________ Year of planting: ______________

Indicator	1	2	3	4	5	6	7	8	9	10 (Preferred)	Observations	Rating the indicator: 1	5	10
1. Does the soil have good structure and tilth?												Cloddy, powdery, massive, or flaky	Some visible crumb structure	Friable, crumbly
2. Is the soil free of compacted layers?												Wire flag bends readily; obvious hardpan; turned roots	Some restrictions to penetrating wire flag and root growth	Easy penetration of wire flag beyond tillage layer
3. Is the soil worked easily?												Many passes and horsepower needed	Medium amount of power and passes needed	Tills easily; requires little power to pull tillage implements
4. Is the soil full of living organisms?												Little or no observable soil life	Some (moving) soil critters	Soil is full of a variety of soil organisms
5. Are earthworms abundant in the soil?												No earthworms	Few earthworms, earthworm holes, or casts	Many earthworms, earthworm holes, and casts
6. Is plant residue present and decomposing?												No residue or not decomposing for long periods	Some plant residue slowly decomposing	Residue in all stages of decomposition; earthy, sweet smell
7. Do crops/weeds appear healthy and vigorous?												Stunted growth, discoloring, uneven stand	Some uneven, stunted growth; slight discoloration	Healthy, vigorously and uniformly growing plants
8. Do plant roots grow well?												Poor root growth and structure; brown or mushy roots	Some fine roots; mostly healthy	Vigorous, healthy root system with desirable root color
9. Does water infiltrate quickly?												Water on surface for long periods after light rain	Water drains slowly; some ponding	No ponding after heavy rain or irrigation
10. Is water available for plant growth?												Droughty soil requires frequent irrigation	Moderate degree of water availability	The right amount of water available at the right time
Other														

GLOSSARY OF SOIL QUALITY TERMS

This glossary is divided into two parts: Soil Quality and Soil Biology. The first section defines soil quality terms and describes some soil quality indicators. The second glossary describes soil organisms and biological processes.

For definitions of other soil terms, see the *Glossary of Soil Science Terms*, 1997, published by the Soil Science Society of America, Madison WI. To order, call the SSSA at 608-273-8080.

SOIL QUALITY TERMS and SELECTED SOIL QUALITY INDICATORS

aggregate stability A measure of how resistant aggregates are to destruction. An aggregate is many soil particles held together in a small mass. A “well-aggregated soil” has a variety of sizes of aggregates and pores, and the aggregates hold up well to forces such as rain, wind, and compaction.

anthropogenic generated by humans. Used to indicate land management practices or soil conditions that are created by people.

assessment of soil quality Estimating the value or quality of soil. It is the process of characterizing change in soil quality, usually by comparative means.

baseline The initial soil condition when monitoring soil quality over time; used to compare subsequent measurements on the same soil to the baseline measurement.

benchmark soil A benchmark soil is one of large extent, one that holds a key position in the soil classification system, or of special significance to farming, engineering, forestry, or other uses. The purpose of benchmark soils is to focus research efforts on soils that have the greatest potential for expansion of data and interpretations.

bulk density (D_b) The density of soil. The weight of soil divided by the volume. The D_b of ag soils normally ranges from 1.0 to 1.8 Mg/m^3.

cation exchange capacity (CEC) The capacity of soil to hold nutrients for plant use. More specifically, CEC is the amount of negative charges available on clay and humus to hold positively charged ions. Expressed as centimoles of charge per kilogram of soil ($cmol_c/kg$).

cotton strip assay Measures the amount of biological activity as determined by the degree of degradation of a standardized strip of cotton buried in the soil.

electrical conductivity (EC) How well the soil conducts an electrical charge. It is a measure of salinity.

fatty acid analysis Examination of the fatty acid methyl esters (FAMEs) in the soil using gas chromatography. Fatty acids are created by soil organisms, so the types of fatty acids found in soil are an indicator of the structure of the soil community.

hydraulic conductivity (K_{sat}) A measure of how easily water flows through soil. (Compare to *infiltration*.)

indicators of soil quality An indirect measure of a soil quality attribute or soil function used to indirectly measure changes in soil functions. Indicators should be adequately sensitive to change, accurately reflect the functioning of the system, and be cost effective and relatively easy and practical to measure. Measures of soil attributes are often divided into three groups of tests.

> **biological soil quality indicators** Measures of living organisms or their activity used as indicators of soil quality. Measuring soil organisms can be done in three general ways.
>
> 1. Measuring the amount of organisms by counting and identifying what organisms are present, or by measuring the *microbial biomass*. Counting may be done to identify *keystone species*, or to determine the ratio between important types of organisms.
> 2. Measuring activity levels. This may be done by measuring the amount of CO_2 given off (*basal respiration*), or rates of decomposition (*cotton strip assay*).
> 3. Measuring cellular components such as the amounts of biological carbon, or nitrogen in the soil, or the types of enzymes or DNA present.
>
> **chemical soil quality indicators** These include tests of *organic matter*, pH, heavy metals, cation exchange capacity, and others.
>
> **physical soil quality indicators** Physical characteristics that vary with management include *bulk density*, *aggregate stability*, and penetration resistance.

infiltration rate The rate at which water can enter soil. (Compare to *hydraulic conductivity*.)

inventory To catalog or list soil resources or qualities.

keystone species A species which, if removed from an ecosystem, causes a dramatic change in the system, and which can be used as an indicator of the functioning of the system.

metabolic quotient (qCO_2) The ratio of microbial activity to microbial biomass.

microbial biomass The total amount of organisms in the soil, excluding macrofauna and plant roots. Microbial biomass is typically determined through *substrate-induced respiration*, or fumigation-extraction methods.

minimum data set (MDS) The smallest set of properties or attributes that can be used to characterize or measure soil quality. The MDS will vary based on the intended land use, soil type, and climate. The first MDS was suggested by Larson and Pierce and included the following:

nutrient availability	total organic C
particle size, texture	labile organic C
plant-available water capacity	soil structure
soil strength (bulk density)	maximum rooting depth
pH electrical conductivity.	

monitoring of soil quality To observe and record soil conditions at regular intervals over time for the purpose of assessing the magnitude and direction of change in soil quality.

organic matter Any material that is part of or originated from living organisms.

> **soil organic matter (SOM)** The whole of organic matter in the soil. It can be divided into three general pools: living biomass of microorganisms, fresh and partially decomposed residues, and the well-decomposed and highly stable organic material. Surface litter may or may not be included as soil organic matter.
>
> **active fraction** The highly-dynamic portion of soil organic matter readily available to soil organisms. May also include the living biomass.
>
> **humus** usually a synonym for *soil organic matter*, but is sometimes a synonym for *stabilized organic matter*.

labile organic matter Organic matter that is available to microorganisms and is easily decomposed.

particulate organic matter (POM) or **light fraction (LF)** The larger (POM) or lighter (LF) components of soil organic matter. They can be separated out by sieving (POM) or centrifugation (LF). This low-density organic matter is thought to represent the *active fraction* of soil organic matter.

stabilized organic matter the pool of soil organic matter that is resistant to biological degradation. The stable organic fraction can be subdivided into humic acids, which are large molecular weight compounds; fulvic acids, which are low molecular weight compounds; and humin, which can not be easily extracted from the soil. These compounds are created through a combination of biological activity and chemical reactions in the soil.

pedo-transfer function (PTF) Formulas that predict difficult-to-measure soil properties from readily obtained properties of the same soil.

pitfall trap a small container (trap) buried so the rim is at the level of the soil surface. It is used to catch soil arthropods.

potentially mineralizable nitrogen (PMN) Organic nitrogen that could become available for use by plants.

reference soil condition The condition of the soil on which quality is based or judged. Soil quality is usually assessed by comparing a soil to a reference condition. The reference condition may be data from a comparable benchmark soil, baseline measurements taken previously on the same soil, or measurements from a similar soil under undisturbed vegetation, or under similar management.

slake test A measure of disintegration of soil structure when exposed to rapid wetting.

soil resilience The capacity of a soil to recover its soil functions after a disturbance. Examples of disturbances are fire, flooding, tillage, or trampling by grazing cattle.

soil resistance The capacity of the soil to maintain soil functions through a disturbance.

soil respiration The amount of carbon dioxide given off by living organisms and roots in the soil.

basal respiration the level of carbon dioxide given off by a soil sample. Basal respiration is a measure of the total biological activity of microorganisms, macroorganisms, and roots.

substrate-induced respiration A measure of the carbon dioxide given off by a soil sample after adding sugar or other food. It is a measure of microbial biomass in the sample.

soil structure The arrangement of particles and pores in the soil. The size, shape, and stability of soil *aggregates*. Soil structure is described with words such as crumbly or cloddy.

scoring function A standardization procedure used to convert measured values or subjective ratings to unitless values usually between 0 and 1. This allows all soil property measurements to be integrated into one value or index for soil quality. The four general types of scoring functions used in soil quality assessments are:

- more is better (higher measurements mean higher soil quality, e.g. OM)
- less is better (lower measurements mean higher soil quality, e.g. salinity)
- optimum range (a moderate range of values is desirable, e.g. pH)
- undesirable range (a specific range of values is undesirable)

soil function A role or task that soil performs such as: sustaining biological activity, diversity, and productivity; regulating and partitioning water and solute flow; filtering, buffering, degrading, and detoxifying potential pollutants; storing and cycling nutrients; providing support for buildings and other structures and protect archaeological treasures.

soil quality The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation. In short, the capacity of the soil to function. There are two aspects of the definition, inherent soil quality and dynamic soil quality.

> **dynamic soil quality** That aspect of soil quality relating to soil properties that change as a result of soil use and management.
>
> **inherent soil quality** That aspect of soil quality relating to a soil's natural composition and properties as influenced by the factors and processes of soil formation.
>
> **soil health** Generally, soil health is synonymous with soil quality except it does not include the inherent soil quality aspect. For example, a soil may have poor inherent soil quality but still have good health.

tilth The overall physical character of soil with regard to its suitability for crop production.

use-dependant properties Mainly includes soil properties that show change and respond to use and management of the soil, such as soil organic matter levels and aggregate stability.

use-invariant properties Mainly includes static soil properties that show little change over time and are not affected by use and management of the soil, such as mineralogy and particle size distribution.

water holding capacity The amount of water that can be held in soil against the pull of gravity.

> **available water holding capacity (AWHC)** The amount of water that can be held by soil and is available for plants to use. It is the total water holding capacity minus the **wilting point.** Wilting point is the amount of water that is held too tightly in soil for plants to extract. Loamy soils and soils high in organic matter have the highest AWHC.

TYPES OF SOIL ORGANISMS AND BIOLOGICAL PROCESSES

actinomycetes A large group of bacteria that grow in long filaments. Actinomycetes generate the smell of “healthy soil,” and are important in decomposing cellulose, chitin, and other hard-to-decompose compounds, especially at higher pH levels. Many produce antibiotics.

aerobic With oxygen. Aerobic organisms require environments with oxygen.

anaerobic Without oxygen. Anaerobic organisms need environments without oxygen such as saturated soils.

arthropods Invertebrate animals with jointed legs. they include insects, crustaceans, sowbugs, arachnids, and others.

bacteria Microscopic, single-celled organisms. they include the photosynthetic cyanobacteria (formerly called blue-green algae), and actinomycetes (filamentous bacteria that give healthy soil its characteristic smell).

bacterial-dominated food web A soil food web in which the ratio of fungal biomass to bacterial biomass is less than one.

comminuters Organisms that shred organic material into smaller pieces.

compost tea An infusion made by leaching water through compost, sometimes with nutrients added, such as molasses and kelp, to encourage certain organisms. Soluble organic matter and the organisms in the compost are rinsed out of the solid phase and left suspended in the water. this "liquid compost" is easier to apply than solid compost.

denitrification A process in which nitrite or nitrate is converted to nitrogen gas (n_2) or nitrous oxide (n_2o) by a few species of anaerobic soil bacteria. Both N_2 and N_2O are volatile and lost to the atmosphere.

detritivores Organisms that eat detritus, that is, dead plants and animals.

ectomycorrhizal fungi A type of mycorrhizal fungi that grows between root cells and forms a sheath around roots, but does not actually invade cells.

endomycorrhizal fungi
A type of mycorrhizal fungi that invades the cells of plant roots.

exudates Root exudates are soluble sugars, amino acids and other compounds secreted by roots.

food web, soil The interconnected community of organisms living all or part of their lives in the soil.

fungal-dominated food web A soil food web in which the ratio of fungal biomass to bacterial biomass is greater than one.

Fungi Multi-celled, non-photosynthetic organisms that are neither plants nor animals. fungal cells form long chains called hyphae and may form fruiting bodies such as mold or mushrooms to disperse spores. some fungi such as yeast are single-celled.

fungivores Organisms that eat fungi.

immobilization The conversion by soil organisms of inorganic nutrients such as ammonium or nitrate into organic compounds that are part of their cells. This makes the nutrients temporarily unavailable to plants. (See *mineralization*.)

lignin A hard-to-degrade compound that is part of the structure of older plants. The carbon rings in lignin can be degraded by fungi.

microbe An imprecise term referring to any microscopic organism. Generally, “microbes” includes bacteria, fungi, and sometimes protozoa.

mineralization The conversion of organic compounds into inorganic, plant-available compounds such as ammonium. This is accomplished by soil organisms as they consume organic matter and excrete wastes. (See *immobilization*.)

mutualists Two species that have a mutually beneficial relationship. For example, mycorrhizal fungi get carbon compounds from plant roots and help deliver water and nutrients to the root.

mycelium A bundle of fungal *hyphae*.

mycorrhizal associations A symbiotic association of certain fungi with roots. The fungi receive energy and nutrients from the plant. The plant receives improved access to water and some nutrients.

nematodes Tiny, usually microscopic, unsegmented worms. Some are parasites of animals or plants. Most live free in the soil.

nitrification A process accomplished by a few groups of aerobic organisms in which ammonia is converted to nitrite and then nitrate.

protozoa Single-celled animals.

rhizosphere The narrow region around roots where most soil biological activity occurs. Soil organisms take advantage of the sloughed and dead root cells and the root exudates found in this region.

saprophytic fungi Fungi that decompose dead organic matter.

trophic levels Levels of the food chain. The first trophic level includes photosynthesizers that get energy from the sun. Organisms that eat photosynthesizers make up the second trophic level. Third trophic level organisms eat those in the second level, and so on. It is a simplified way of thinking of the food web; some organisms eat members of several trophic levels.

VAM (vesicular arbuscular mycorrhizae) The group of endomycorrhizal fungi important in non-woody plants, including many agricultural crops.

Soil Quality Web Sites

For more soil quality web sites, see links from the Soil Quality Institute page and the UC-Davis page.

Soil Quality Institute
http://www.statlab.iastate.edu/survey/SQI/sqihome.shtml
Many SQI products can be downloaded from this site. Includes links to other soil quality sites.

NRCS Science and Technology Consortium
http://www.ncg.nrcs.usda.gov/consortium/consort.html
Access other NRCS Institutes from this page:

Conservation Technology Information Center
http://www.ctic.purdue.edu
A rich source of information about conservation tillage and residue management. For a list of publications, visit their web page or call 317-494-9555.

University of California--Davis Sustainable Agriculture Research and Education Program
http://www.sarep.ucdavis.edu/soil/
Includes a list of internet links to soil quality and soil management information.
SAREP has pulled together the following two collections of resources. They can be ordered from: SAREP, University of California, One Shields Ave., Davis,CA 95616. Tel. 530-752-7556.

Cover Crops: Resources for Education and Extension. 1997. David Chaney and Ann D. Mayse (Editors). UC Division of Agriculture and Natural Resources, Sustainable Agriculture Research and Education Program, Davis, CA.

Soil Quality: Resources for Education and Extension. 1999. David Chaney and Ann D. Mayse (Editors). UC Division of Agriculture and Natural Resources, Sustainable Agriculture Research and Education Program, Davis, CA. Available February 1999.

National Association of Conservation Districts
http://www.nacdnet.org/
Check out their educational resources, and their list of local contact information.

Soil and Water Conservation Society
http://www.swcs.org/

Sustainable Agriculture Network
http://www.sare.org/san/
Look here for publications, and for information about grants available from the Sustainable Agriculture Research and Education (SARE) Program. SARE provides grants for demonstration and education projects.

Soil Quality Institute Products

For a current list of Soil Quality Institute products, visit the SQI web page at: http://www.statlab.iastate.edu/survey/SQI/sqihome.shtml

SQI products may be organized in the binder as follows.

Soil Quality—general 190-22
Soil Quality Institute pamphlet
Presentations and papers about soil quality
Soil Quality Information sheets
Microbiotic Crusts

Inventory and Assessment 190-22-11
Soil Quality Test Kit Guide

Management practices 190-22-12
Agronomy Tech Notes
Phosphorus in Agriculture

Soil Biology 190-22-15
Soil Biology Primer

Outreach/Education
Soil Quality Card Design Guide and sample cards

USDA NRCS Natural Resources Conservation Service | Soil Quality Institute

Products and Services Catalog

Visit our web site at http://www.statlab.iastate.edu/survey/SQI/sqihome.shtml. **Most of our products and services are posted there. Hard copies can be ordered through the Web site.**

Publications

Soil Quality Institute Business Plan
Describes the Institute's work plans for the current fiscal year. It is available on the Web site.

Soil Quality Institute Pamphlet
Describes the mission and vision of the Soil Quality Institute. It introduces NRCS staff and partners to the concept of soil quality, soil quality resource concerns, and implementation strategies to achieve soil quality.

"Soil Quality – A Multitude of Approaches" Presentation
Describes the soil quality concept and approaches to soil quality assessment. The presentation was the keynote address at the Kearney Foundation Symposium, "California Soil Quality: From Critical Research to Sustainable Management" (March 1997). It is available from the Web site.

Soil Quality-Agronomy Technical Notes
Intended for NRCS field staff use. This series of 2 to 4-page tech notes describes the effects of conservation practices on soil quality. They are available from the Web site: http://www.statlab.iastate.edu/survey/SQI/agronomy.shtml.
Current topics:

Cover and Green Manure Crop Benefits to Soil Quality	(Technical Note #1)
Conservation Crop Rotation Effects on Soil Quality	(Technical Note #2)
Effects of Residue Management, No-till on Soil Quality	(Technical Note #3)
Effect of Soil Quality on Nutrient Efficiency	(Technical Note #4)
Herbicides	(Technical Note #5)
Legumes and Soil Quality	(Technical Note #6)
Effects of Erosion on Soil Productivity and Soil Quality	(Technical Note #7)

"Assessment of Soil Quality" Paper
Discusses the assessment of soil quality at various levels of scale, ranging from the field level to the national level. It reviews the definition of soil quality with a discussion of soil quality indicators, reference values, and assessments. The reference is: Mausbach, M.J. and C.A. Seybold. 1998. Assessment of Soil Quality. p. 33-43. In: R. Lal (ed.) Soil Quality and Agricultural Sustainability. Ann Arbor Press, Chelsea, MI.

"Soil Quality Considerations in the Conversion of CRP Land to Crop Production" Presentation
Discusses the beneficial effects of CRP on soil quality, the concerns of returning CRP land to crop production, and alternative systems to protect the soil quality benefits obtained from 10 years of grass cover. The presentation was made at the CRP-96 Conference, "Preparing for Future CRP Land Use in the Central and Southern Great Plains", Amarillo, TX (October 1996). It is available from the Web site.

"The Soil Quality Concept" Booklet
Contains eight key papers on the concepts of soil quality. It provides information and references on soil quality for NRCS staff to use in integrating soil quality with conservation planning and natural resource inventory activities (October 1996).

"Soil Biology Primer" Publication
An introduction to the living soil system for NRCS field staff, partners, and customers. This full color set of 8 units describes the importance of soil organisms and the soil food web to soil productivity and water and air quality. It addresses how soil organisms are affected by management practices. The Primer is a collaborative effort of the SQI, the Conservation Technology Information Center, Oregon State University, Ohio State University, and other scientists. (Available June 1999).

"Soil Changes Following 18 Years of Protection from Grazing in Arizona Chaparral" Paper
Results of a study that compared changes in physical and chemical properties of a chaparral soil protected from grazing for 18 years. It describes these changes relative to succession and threshold paradigms. The reference to this paper is Brejda, John J. 1997. Soil Changes Following 18 Years of Protection from Grazing in Arizona Chaparral. The Southwestern Naturalist 42 (4): p. 478-487.

Soil Quality Information Sheets
Introduces soil quality to NRCS staff, partners, and customers. The National Soil Survey Center prepared these one-page, full color sheets in cooperation with the SQI and the ARS National Soil Tilth Laboratory. Current topics include:

Soil Quality – Introduction	(April 1996)
Indicators for Soil Quality Evaluation	(April 1996)
Soil Quality Indicators: Organic Matter	(April 1996)
Soil Quality Indicators: Soil Crusts	(April 1996)
Soil Quality Indicators: Aggregate Stability	(April 1996)
Soil Quality Indicators: pH	(May 1998)
Soil Quality Indicators: Infiltration	(May 1998)
Soil Quality Resource Concerns: Soil Erosion	(April 1996)
Soil Quality Resource Concerns: Sediment Deposition on Cropland	(April 1996)
Soil Quality Resource Concerns: Compaction	(April 1996)
Soil Quality Resource Concerns: Salinization	(May 1998)
Soil Quality Resource Concerns: Pesticides	(May 1998)
Soil Quality Resource Concerns: Available Water Capacity	(May 1998)
Soil Quality Resource Concerns: Soil Biodiversity	(May 1998)

For more information, contact Gary Muckel, National Soil Survey Center, (402) 437-4148; Email gmuckel@nssc.nrcs.usda.gov. The sheets are available from the Web site.

"Soil Resilience: A Fundamental Component of Soil Quality." Paper
Addresses the concept of soil resilience and its relationship to soil quality. It provides a review of the literature on the assessment and quantification of resilience. The paper was prepared for the Natl. Coop. Soil Survey Conf. in Baton Rouge, LA (June 1997). The reference to this paper is: Seybold, C.A., J.E. Herrick, and J.J. Brejda. 1999. Soil resilience: A fundamental component of soil quality. Soil Science 164:224-234.

County Economic, Agriculture, and Environmental Health Index
Patterned after an indexing method developed by Gomez et al., 1996. The objective of this study is to explore using existing national databases like NRI and NASS statistics to evaluate counties on an MLRA basis with standards or thresholds unique to the agricultural community and natural resources in each MLRA. A pilot test of this procedure is underway. The partners in this study are the Natural Resources Inventory and Analysis Institute and the Soil Quality Institute with assistance from NRCS scientists in Temple, Texas. For additional information, contact Lee Norfleet, SQI, (334) 844-4741, ext. 176; Email norfleet@eng.auburn.edu or David Buland, NRIAI, (254) 770-6522; Email buland@brcsun0.tamu.edu.

“Introduction to Microbiotic Crusts” Pamphlet
Discusses microbiotic crusts, including what they are, where they occur, what their role is, and how they are affected by disturbance. This 13-page, color pamphlet was developed by the SQI in cooperation with the Grazing Lands Technology Institute.

“Phosphorus in Agriculture” Pamphlet
Describes the importance of phosphorus in plant growth and the environmental impacts and management of agricultural phosphorus (January 1998). It is available on the Web site.

Soil Rating for Plant Growth (SRPG) Report
Details the computerized SRPG rating system for arraying soils according to their inherent productivity and suitability for crops. The system is suitable for national-level bid evaluations. The report was developed for the Soil Quality Institute in conjunction with the National Soil Survey Center. For additional information, contact H. Ray Sinclair, Jr., NSSC, at (402) 437-5699. It is available from the Web site.

“Quantification of Soil Quality” Paper
Discusses various approaches to quantifying soil quality and recommends a framework for measuring and assessing soil quality. It reviews the definition, indicators, and indices of soil quality; minimum data sets; and effects of scale. This paper was prepared for an international symposium on Carbon Sequestration in Soils held in Columbus, OH (July 1996). The reference to this paper is Seybold, C.A., M.J. Mausbach, D.L. Karlen, and H.H. Rogers. 1998. Quantification of soil quality. p. 387-404. In: R. Lal, J.M. Kimble, R.F. Follet, and B.A. Steward (eds.) Soil processes and the carbon cycle. Advances in Soil Science. Chapt, 27. CRC Press, Boca Raton, Florida.

Soil Quality Card Design Guide
The Soil Quality Card Design Guide gives instructions for conducting farmer focus sessions to develop local Soil Quality/Health Cards. A Card is a qualitative field assessment tool developed by farmers for farmers. It is a do-it-yourself rating guide for farmers to monitor soil quality from year to year or to compare practices. Conservationists can use it in locally led conservation, education, and information activities. The SQI developed the procedures and the Guide in collaboration with Oregon State University, OSU Cooperative Extension Service, University of Maryland, and NRCS staff in OR, MD, MT, ND, and NM. (Available on the Web and in print in May 1999).

Soil Quality Card – Willamette Valley, Oregon
Developed by farmers in the Willamette Valley of Oregon. It is a do-it-yourself rating guide for farmers to monitor soil quality over time or to compare practices. The SQI helped develop the Card in collaboration with Oregon State University, OSU Cooperative Extension Service, SWCDs, and NRCS staff in OR. For a booklet of 50 cards, contact Publications Orders, Extension and Station Communications, Oregon State University, 422 Kerr Administration, Corvallis, OR 97331-2119. FAX: (541) 737-0817.

“Soil Quality Symbol” Clipart
Artwork for soil quality was developed by the SQI and is available for use by anyone needing a symbol for soil quality. Please send a courtesy copy of all documents displaying this artwork to the SQI. The graphic files may be downloaded from a link on the SQI homepage. The files are also available via anonymous ftp at ftp://ftp.nstl.gov/software.sqsymbol.

Soil Quality Clipart

The SQI designed several clipart images to represent soil and its many functions (infiltration, nutrient cycling, productivity, structural support, filtering and buffering, and partitioning water and solute flow). Also available for free use is a set of black-and-white images depicting farmers using a soil quality/health card. Images can be downloaded from the SQI homepage. The files are also available via anonymous ftp at ftp://ftp.nstl.gov/software.sqclip.

Soil Quality Test Kit Guide

Adapted from the ARS Soil Health Kit and designed for use by NRCS field staff, SWCDs, and ag consultants. Measurements made with the kit are pH, electrical conductivity, soil nitrate-N, bulk density, respiration, infiltration, aggregate stability, soil slaking, earthworms, water quality, and soil physical observations and estimations. The Guide includes instructions for conducting the tests and building a kit as well as a section on interpretations for evaluating test results. The Guide is available from the Web site.

Soil Quality Reference Soils Map

The Soil Quality Institute and Auburn University collaborated to establish a set of 27 soils for use as a standard reference set for soil quality research. The soils were selected on the basis of acreage, land use, economics, and environmental importance. A US map of the reference soils can be viewed from the 'Soil Quality Reference Soils' link on the SQI homepage.

Training

Farmer Workshops for Locally Developed Conservation Tools (Soil Quality Cards)

Prepares NRCS staff and partners to conduct farmer/conservationist participatory workshops and to develop local soil quality/health cards. The basic principles of farmer participatory action and learning are presented. Participants practice a step-wise approach to lead farmers in identifying soil quality indicators, developing a rating system, and designing a local soil quality/health card. Included are activities to enhance facilitation skills for farmer meetings and locally led conservation. Take-home strategies to market and develop local soil health cards are developed. (Available on request to the SQI)

Soil Quality: Assessment and Applications for Field Staff

The Soil Quality Institute and National Employee Development Center (NEDC) are developing a soil quality course designed to provide field personnel with an overall understanding of soil quality that will enhance our agency's ability to provide conservation technical assistance. Participants will be able to recognize soil quality concerns, communicate those concerns to land managers and users, and provide alternatives to remedy those concerns in a manner that meets requirements of the agency and the land manager. The course will be offered as train-the-trainer sessions in Fiscal Year 2000. After the first year, NEDC will offer the course based on demand.

Academic Soil Quality Resources

Journal articles and books are available from major agricultural libraries. Books can be purchased from the publisher (phone numbers are shown) or through most university bookstores.

Journal Articles

Karlen, D.L., M.J. Mausbach, J.W. Doran, R.G. Cline, R.F. Harris, and G.E. Schuman. 1997. Soil quality: A concept, definition, and framework for evaluation. *Soil Sci. Soc. Amer. J.* 61:4-10.

Seybold, C.A., M.J. Mausbach, D.L. Karlen, and H.H. Rogers. 1998. Quantification of soil quality. p. 387-404. In: R. Lal, J.M. Kimble, R.F. Follett, and B.A. Stewart (eds.) *Soil Processes and the Carbon Cycle*. CRC Press, Boca Raton.

Doran, J.W., M. Sarrantonio, and M.A. Liebig. 1996. Soil health and sustainability. p.1-54. In: D.L. Sparks (ed.) *Advances in Agronomy*. Vol. 56. Academic Press, San Diego, CA.

Journal Special Features on Soil Quality

Journal of Soil and Water Conservation. 1995. Volume 50 (May-June)

Contents:

American Journal of Alternative Agriculture. 1992. Volume 7(1).

Contents:

Books

Doran, J.W., D.C. Coleman, D.F. Bezdicek, and B.A. Stewart (Editors). 1994. *Defining Soil Quality for a Sustainable Environment.* SSSA Spec. Publ. 35. Soil Science Society of America, Madison, WI. (608-273-8080)

Chapters:

- Defining and Assessing Soil Quality
- Descriptive Aspects of Soil Quality/Health
- The Dynamics of Soil Quality as a Measure of Sustainable Management
- A Framework for Evaluating Physical and Chemical Indicators of Soil Quality
- Microbial Indicators of Soil Quality
- Faunal Indicators of Soil Quality
- Soil Enzyme Activities as Indicators of Soil Quality
- Assessment and Significance of Biologically Active Soil Organic Nitrogen
- Multiple Variable Indicator Kriging: A Procedure for Integrating Soil Quality Indicators
- Descriptive and Analytical Characterization of Soil Quality/Health
- Biologically Active Soil Organics: A Case of Double Identity
- Terrestrial Carbon Pools in Grasslands and Agricultural Soils: Preliminary Data from the Corn Belt
- Carbon and Nitrogen Mineralization as Influenced by Long-Term Soil and Crop Residue Management Systems in Australia
- Biologically Active Pools of Carbon and Nitrogen in Tallgrass Prairie Soil
- A Method to Determine Long-Term Carbon and Nutrient Mineralization in Soils
- Contributions of Soil Aggregation and Soil Quality
- Microbial Biomass as an Indicator of Soil Quality: Effects of Long-term Management and Recent Soil Amendments
- The Response of Nematode Trophic Groups to Organic and Inorganic Nutrient Inputs in Agroecosystems

Doran, J.W. and A.J. Jones (Editors). 1996. *Methods for Assessing Soil Quality*. SSSA Spec. Publ. 49. Soil Science Society of America, Madison, WI. (608-273-8080)

Chapters:

- Introduction: Importance of Soil Quality to Health and Sustainable Land Management
- Quantitative Indicators of Soil Quality: A Minimum Data Set
- Farmer-Based Assessment of Soil Quality: A Soil Health Scorecard
- A Conceptual Framework for Assessment and Management of Soil Quality and Health
- On-Farm Assessment of Soil Quality and Health
- Standardized Methods, Sampling, and Sample Pretreatment
- Physical Tests for Monitoring Soil Quality
- Soil Water Parameters and Soil Quality
- Soil Organic Carbon and Nitrogen
- Measurement and Use of pH and Electrical Conductivity for Soil Quality Analysis
- Assessing Soil Nitrogen, Phosphorus, and Potassium for Crop Nutrition and Environmental Risk
- Role of Microbial Biomass Carbon and Nitrogen in Soil Quality
- Potentially Mineralizable Nitrogen as an Indicator of Biologically Active Soil Nitrogen
- Field and Laboratory Tests of Soil Respiration
- Soil Enzyme Activities and Biodiversity Measurements as Integrative Microbiological Indicators
- Soil Invertebrates as Indicators of Soil Quality
- Tests for Risk Assessment of Root Infection by Plant Pathogens
- Assessing Organic Chemical Contaminants in Soil
- Soil Quality Assessment—Preliminary Case Studies

Gershuny, G, and J. Smillie. 1995. *The Soul of the Soil: A Guide to Ecological Soil Management.* agAcess, Davis, CA. (916-756-7177)

Chapters:
- Introduction
- Understanding the Soil System
- Observing and Evaluating Your Soil
- Soil Management Practices
- The Marketplace and Organic Certification

Gregorich, E.G. and M.R. Carter (Editors). 1997. *Soil Quality for Crop Production and Ecosystem Health.* Developments in Soil Science 25. Elsevier, New York. (1-888-437-4636)

Chapters:
- Concepts of Soil Quality and Their Significance
- Physical Attributes of Soil Quality
- Chemical Attributes and Processes Affecting Soil Quality
- Biological Attributes of Soil Quality
- An Ecosystem Perspective of Soil Quality
- Soil Quality Indicators: Pedological Aspects
- Effects of Soil Redistribution on Soil Quality: Pedon, Landscape, and Regional Scales
- Standardization for Soil Quality Attributes
- Soil Quality Control
- Pedotransfer Functions to Evaluate Soil Quality
- Statistical Approaches to the Analysis of Soil Quality Data
- Soil Organic Matter Dynamics and Their Relationship to Soil Quality
- Socioeconomics in Soil-Conserving Agricultural Systems: Implications for Soil Quality
- Toward a Framework for Soil Quality Assessment and Prediction
- Establishing a Benchmark System for Monitoring Soil Quality in Canada
- Case Study of Soil Quality in South-eastern Australia: Management of Structure for Roots in Duplex Soils
- Case Studies of Soil Quality in the Canadian Prairies: Long-term Field Experiments
- Soil Organic Matter and Soil Quality--Lessons Learned From Long-term Experiments at Askov and Rothamsted

Lal, R. (Editor). 1998. *Soil Quality and Soil Erosion*. CRC Press, Boca Raton. (1-800-272-7737)

Chapters:
- Effects of Long-term Cropping on Organic Matter Content of Soils--Implications for Soil Quality
- Use of Winter Cover Crops to Conserve Soil and Water Quality in the San Luis Valley of South Central Colorado
- Soil Quality: Post CRP Changes with Tillage and Cropping
- Soil Quality and Environmental Impact of Dryland Residue Management Systems
- Rx for Soil Quality = Long-term No-till
- Whole-soil Knowledge and Management: A Foundation for Soil Quality
- The Effect of Forest Management on Erosion and Soil Productivity
- Rangeland Soil Erosion and Soil Quality: Role of Soil Resistance, Resilience, and Disturbance Regime
- Relationship between Soil Quality and Erosion
- Erosion Impact on Crop Yield for Selected Soils of Northcentral USA
- Erosion Impact on Soil Quality in the Tropics
- Applying Soil Quality Concepts for Combating Soil Erosion

Lal, R., J.M. Kimble, R.F. Follet, and B.A. Stewart (Editor). 1998. *Management of Carbon Sequestration in Soil*. CRC Press, Boca Raton. (1-800-272-7737)

Selected Chapters:

Use and Soil C Pools in Terrestrial Ecosystems
Effects of Tillage on Profile Soil Carbon Distribution in the Northern Great Plains of the U.S.
Tillage Methods and Carbon Dioxide Loss: Fall Versus Spring Tillage
The Impact of Soil Conservation Policies on Carbon Sequestration in Agricultural Soils of the Central United States
Crop Management Effects on Organic Carbon in Semi-Arid Pacific Northwest Soils
Carbon Storage in Soils under Continuous Cereal Grain Cropping: N Fertilizer and Straw
Effects of Different Management Systems on Carbon and Nitrogen Dynamics of Various Soils
Enhancing Carbon Sequestration in CRP-Managed Land
Forested Soil Carbon Storage in Landscapes of the Northern Great Lakes Region
Forages and Row Cropping Effects on Soil Organic Carbon and Nitrogen Contents
Carbon Storage in Grassland Soils as Related to N and S Fertilizers

Magdoff, F. 1992. *Building Soils for Better Crops: Organic Matter Management*. University of Nebraska Press, Lincoln, NE. (1-800-755-1105)

Chapters:

What is soil organic matter?
The Living Soil
Why is Soil Organic Matter So Important?
Organic Matter Levels in Soils
Organic Matter Management—the Balancing Act
Animal Manures
Cover Crops
Crop Rotations
Reduced Tillage
Composts
Decreasing Soil Erosion
Putting It All Together
Organic Matter Dynamics and Nutrient Availability
The Chemistry of Soil Organic Matter

Pankhurst, C.E., B.M. Doube, and V.V.S.R. Gupta (Editors). 1997. *Biological Indicators of Soil Health*. CAB International, New York. (1-800-528-4841)

Chapters:

Defining and Assessing Soil Health and Sustainable Productivity
Soil Health: Its Relationship to Ecosystem Health
Rationale for Developing Bioindicators of Soil Health
Bioindicators: Perspectives and Potential Value for Landusers, Researchers and Policy Makers
Soil Microbial Biomass, Activity and Nutrient Cycling as Indicators of Soil Health
Soil Enzyme Activities as Integrative Indicators of Soil Health
Soil Microflora as Bioindicators of Soil Health
Potential Use of Plant Root Pathogens as Bioindicators of Soil Health
Soil Microfauna as Bioindicators of Soil Health
Community Structure of Soil Arthropods as a Bioindicator of Soil Health
Can the Abundance or Activity of Soil Macrofauna be used to Indicate the Biological Health of Soils?
Biomonitoring of Soil Health by Plants
Bioindicators to Detect Contamination of Soils with Special Reference to Heavy Metals
Chemical and Molecular Approaches for Rapid Assessment of the Biological Status of Soils
Use of Genetically Modified Microbial Biosensors for Soil Ecotoxicity Testing
Biological Indicators of Soil Health: Synthesis

Regional and Local Resources

Some of the most valuable soil quality publications are specific to your region. On this page, record contact information for people and organizations that provide regional publications and technical help.

NRCS state soil quality technical specialist:

Regional technical team or consortia:

State conservation agencies:

ARS Research Locations:

Cooperative Extension Specialists and Experiment Stations:

Other:

NRCS REGIONAL TECHNICAL RESOURCES

For soil quality and soil management technical information for your region, contact one of the following.

East Region

Mid-Atlantic Interdisciplinary Resource Team (IRT) has a homepage at http://www.de.nrcs.usda.gov/irt/www_irt.htm, and can be reached through your state IRT representative:

The New England Interdisciplinary Resources Technical Team (IRT) has a homepage at http://neirtnt.ct.nrcs.usda.gov/

Midwest Region

State Soil Scientist
USDA/NRCS
1902 Fox Drive
Champaign, IL 61820-7335

MLRA Leader/State Soil Scientist
USDA/NRCS
6013 Lakeside Boulevard
Indianapolis, IN 46278-2933

State Soil Scientist
USDA/NRCS
Federal Building
210 Walnut Street, STE 693
Des Moines, IA 50309-2180

Soils Liaison
USDA/NRCS
1405 South Harrison Road
Room 101
East Lansing, MI 48823-5243

MLRA Leader/State Soil Scientist
USDA/NRCS
375 Jackson Street, STE 600
St. Paul, MN 55101-1854

Soils Liaison
USDA/NRCS
Parkade Center, Suite 250
601 Business Loop 70 West
Columbia, MO 65203-2546

Soils Liaison
USDA/NRCS
200 North High Street
Room 522
Columbus, OH 43215-2478

State Soil Scientist
USDA/NRCS
6515 Watts Road, Suite 200
Madison, WI 53719-2726

Northern Plains Region

NRCS Soil Quality Team
P.O. Box 400
40335 Co. Rd. GG — 970-345-2259
Akron, CO 80720 — 970-345-2088 [Fax]

Chuck Gordon
NRCS — 406-587-6818
Federal Building, Room 443 — 406-587-6761 [Fax]
10 East Babcock St. — Voice Com: 9000-587-1180
Bozeman, MT 59715 — cgordon@mt.nrcs.usda.gov

South Central Region

Jerry Daigle — 318-473-7757
USDA/NRCS — 318-473-7771 [Fax]
3737 Government Street — jdaigle@la.nrcs.usda.gov
Alexandria, LA 71302

Southeast Region

For up-to-date information, visit the Southeast Region web site at www.ga.nrcs.usda.gov
Click on “Southeast Regional Teams” for a map of and links to regional technical resources.

West Region

Neil Peterson
Resource Soil Scientist for Idaho
West Soil Technical Consortium

USDA NRCS Idaho State Office — 208-378-5721
9173 West Barnes Drive, Suite C — 208-378-5735 [Fax]
Boise, ID 83709 — Voice Com: 9000-881-1465

AGRICULTURAL RESEARCH SERVICE

Contact information for ARS research locations are listed at: http://www.ars-grin.gov/ars/loc.html

Or contact the office of your area director:

Richard L. Dunkle
Director, Midwest Area
USDA-Agricultural Research Service
1815 N. University St.
Peoria, Illinois 61604
309-681-6603
309-681-6684 [Fax]
dunkler@ars.usda.gov

Wilda H. Martinez
Director, North Atlantic Area
USDA/ARS/NAA
600 East Mermaid Lane
Wyndmoor, PA. 19038
(215)233-6593
(215)233-6719 [Fax]
wmartinez@ars.usda.gov

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Athens, Ga. 30604-5677
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COOPERATIVE EXTENSION SERVICE

A directory and links to Extension services, agricultural universities, and experiment stations in every state can be found at the Agricultural Cooperative Extension Service Listing: http://www.ansi.okstate.edu/internet/agexten.html

Search for Extension publications from these web pages:

QUERRI data base http://idea.exnet.iastate.edu/querri/
This database allows you to search for University Extension materials from 12 Midwestern states: North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Michigan, and Ohio.

E-Answers http://www.e-answers.org/
Includes full text of publications generated by the Cooperative Extension Service or Agricultural Experiment Station in at least 30 states.

PenPages http://www.penpages.psu.edu/
Features on-line text of Extension publications and newsletters generated by several land-grant universities around the country.

The Soil Quality Symbol

The symbol for soil quality embodies the circle of life (earth), the natural resources, their dependence on soil, and the human dependence on the health of it all. Two corn stalks represent agriculture and people working together to produce food and a bountiful, healthy life. The tree symbolizes all natural resources, including forests, rangelands, wildlands, and home garden. The shaded background within the circle is the soil, the warm, sustaining resource that is the foundation of all life. A circle of harmony and protection embraces these resources and the open sky (a raindrop) from which rain replenishes living things. Light from the sun's rays warms and energizes all.

To download this symbol, visit the SQI web site at
www.statlab.iastate.edu/survey/SQI/sqihome.shtml